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August 26, 1999

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## Box Patent Application

Assistant Commissioner for Patents  
Washington, DC 20231

Presented for filing is a new provisional-to-utility patent application of:

BOSTON  
DELAWARE  
NEW YORK

SILICON VALLEY  
SOUTHERN CALIFORNIA  
TWIN CITIES  
WASHINGTON, DC

Applicant: CLAUS TONDERING  
Title: REGULATING USAGE OF COMPUTER RESOURCES

Enclosed are the following papers, including all those required to receive a filing date under 37 CFR §1.53(b):

	<u>Pages</u>
Specification	14
Claims	4
Abstract	1
Declaration (unexecuted)	2
Drawing	1
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Enclosures:

- Postcard.

Under 35 U.S.C. §119(e)(1), this application claims the benefit of prior U.S. provisional application 60/097,912, filed 08/26/98.

"EXPRESS MAIL" Mailing Label Number EL163701974US

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BOX PATENT APPLICATION

August 26, 1999

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08/26/99  
U.S. PTO  
FEE

Basic filing fee	\$ 760.00
Total claims in excess of 20 times \$18.00	18.00
Independent claims in excess of 3 times \$78.00	78.00
Multiple dependent claims	0.00
Total filing fee:	\$ 856.00

Under 37 CFR §1.53(d), no filing fee is being paid at this time.

If this application is found to be INCOMPLETE, or if a telephone conference would otherwise be helpful, please call the undersigned at 212/765-5070.

Kindly acknowledge receipt of this application by returning the enclosed postcard.

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Enclosures

100539.LJ1

APPLICATION  
FOR  
UNITED STATES LETTERS PATENT

TITLE: REGULATING USAGE OF COMPUTER RESOURCES  
APPLICANT: CLAUS TONDERING

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REGULATING USAGE OF COMPUTER RESOURCES

**CROSS-REFERENCE TO RELATED APPLICATIONS**

This application claims the priority of United States Provisional Patent Application No. 60/097,912, filed August 26, 1998.

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**BACKGROUND OF THE INVENTION**

The present invention relates generally to networks, and more particularly, to a method for regulating the usage of resources in such networks.

Networks, such as local area networks (LANs), are used for interconnecting many different devices, such as computers and peripherals, to allow users to communicate with one another. Further, these networks are used to allow users to share access to the connected peripherals. The LAN may be a heterogeneous LAN in which many different communication protocols are carried on a single Ethernet or token-ring medium. Examples of different protocols are IPX, which is typically used by DOS-based PCs and UDP/IP, which is typically used by UNIX-based work stations. Each type of device may be adapted through software to communicate using multiple different protocols.

A peripheral also can include software. The software is in the form of multiple protocol stack modules that allow the peripheral to communicate using multiple protocols in order to be shared on a heterogeneous LAN. A protocol stack is a software module that processes packets of data which are received from or transmitted to the LAN using the corresponding protocol. The protocol stacks in the associated lower-level software for

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network communications are typically stored and executed on a network interface device that may be embedded in or attached to the peripheral. The network interface device serves as an interface which allows the peripheral to communicate with other network devices via the LAN.

5 Due to the large number of users and devices associated with the LAN, various potentially unrelated devices (*e.g.*, spawned by separate applications) compete for finite system resources, such as memory allocation space, disk access, and processor time. A device typically requests usage of a resource from the system's operating system. If the resource is not being used, the operating system grants access. In some networking environments, the device is allowed to use and hold the resource indefinitely. This can block other processes access to the same resource. This results in delays in or a potential catastrophic failure of the system. This may occur, for example, when one device is more important and/or urgent than another. For example, the industrial process control of a nuclear reactor may be more important than down loading information from the Internet.

10 Many techniques have been developed to regulate computer resource usage in a network system. For example, a maximum time limit for the usage of a given resource may be used. One drawback to this technique is that a specific device may require more than the specific maximum time limit to execute a specific resource.

15 Another known technique is to fix a process time that is substantially the same for each resource. Again, this technique has certain drawbacks that include not allowing a process to execute a resource for an extended period of time to perform an important function.

## SUMMARY OF THE INVENTION

In general, in one aspect, the invention is directed to a method of managing usage in a network system that includes indicating available credit for usage of a resource, and regulating usage of the resource by a process based on the indicated available credit.

5        Implementations of the invention include one or more of the following. The resource may be a memory space or system processor time. The network may be an embedded computer system, or may operate in a real-time networking environment. The method may be modeled as a leaky bucket. The available credit may be modified by adjusting a maximum resource usage value of the resource. A message may be sent to a process waiting to use a resource when the available credit exceeds a specified amount.

10      In another aspect, the invention is directed to a method of managing a plurality of resources in a network having a plurality of devices that includes creating a software tool corresponding to each of the plurality of resources on each of the plurality of devices accessing the plurality of resources . The software tool may be used to regulate the usage of any of the plurality of resources by any of the plurality of devices.

15      Implementations of the invention include one or more of the following. A descriptor representative of any of the software tools may be allocated to any of the plurality of devices. Each software tool may be associated with a maximum usage level. The maximum usage level of the software tool may be decremented in response to the use of the resource associated with the tool by any of the devices. An available credit based on the usage of the resource associated with the tool may be calculated as a function of the maximum usage level. A device waiting to use the resource associated with the tool can be informed of the available credit. A message may be sent to a network address associated with the waiting device to indicate when the available credit exceeds a specified usage level. The maximum

usage level may be incremented to at least correspond to the specified usage level. The maximum usage level may be overridden to allow a device access to one of the resources. The software tool may be destroyed in response to a request from one of the devices.

In yet another aspect, the invention is directed to a network including a plurality of devices having a plurality of resources running in the network. The network may include computer software residing on a computer readable medium at each device accessing the plurality of resources that cause the device to indicate available credit for usage of one of the resources, and regulates the usage of the resource by a device based on the indicated available credit.

Other advantages will be come apparent from the following description including the drawings and the claims.

#### **BRIEF DESCRIPTION OF THE DRAWING**

FIG. 1 is a block diagram of an exemplary network system.

#### **DESCRIPTION OF THE PREFERRED EMBODIMENTS**

A common problem in a network system is that certain resources, such as memory, are substantially consumed by devices, such as computers, connected to the network system. This causes other devices connected to the system to delay executing the same process. Thus, urgent/important processes are unable to be accessed by these devices. This is because the computer system has a limited number of finite resources. After a threshold of these resources has been reached, the entire system can fail.

Accordingly, the present inventor has discovered a method that can control access to resources in a network system in an optimal manner. The preferred method includes a software tool that can be programmed into a device connected to the system. In accordance with the preferred method, the software tool can be used to model a resource of the network.

5 The software tool which will be referred to as a "leaky bucket" and may have a hole in its bottom. In accordance with the preferred method, this bucket may have three characteristics. First, water may be poured into the bucket. However, the bucket will become full if too much water is poured into the bucket. Second, water may flow out of the hole in the bottom of the bucket at a constant rate. Thus, water may be poured into the bucket at this constant rate. Finally, if the bucket is not full of water, additional water may be poured into the bucket at a rate that is higher than the rate at which water flows out of the hole. However, the size of the bucket sets a maximum value for the amount of water that can be added into the bucket.

10 The network system may be an embedded system. An embedded system is a special purpose networking environment in which all processes cooperate to achieve a common goal. Certain examples of such a system include a network router, a telephone switch, and an industrial control system. Preferably, the software tool is accessible through a programming interface. Further, the software tool is an abstract object. This means that the software tool is not directly associated with a queue or any other object in the system.

15 The preferred method for allocating computer resources in a network is a software tool that a programmer may explicitly set-up and use when writing code for a particular device connected to the network, such as a network switch, a computer, or other similar network device. Alternatively, the manufacturer of an embedded system could implement, as a standard programming practice, that all of the programmers use the preferred method for

accessing specific resources in a specific manner. In the preferred method, the leaky bucket is created for each resource. The preferred method may be programmed in a suitable programming language, such as C, C++, Ada, Pascal, Fortran, Java, or assembly language. Examples of resources that can be regulated include memory, disk access, and system process time.

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FIG. 1 illustrates a block diagram of an example network in which the preferred method may be used. The preferred method may also be used in any real-time networking environment. FIG. 1 illustrates a LAN 10 as an Ethernet medium that has a bus-type architecture. A token-ring medium having a ring-type architecture can also be used. Connected to the LAN 10 is a personal computer (PC) 20 which may serve as a system administrator's computer, a PC 30 which can serve as a print server for printers 85 and 95 and workstations 60. The workstations 60 is any general purpose or dedicated computer including PCs, Apples, Unix, and other computer workstations that can run an operating system. For example, the operating system may be a windows-based operating system. A file server 70 may allow shared access to a network disk 75 and a network expansion board 100 can permit shared access to a printer 105. A network expansion device 120 may provide shared access to a printer 122. In addition, a network interface 125 can allow shared access to a copier 116 via a multiple device controller 130.

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In operation, the workstations 60 may access resources from other devices connected to the LAN 10. In some cases, multiple workstations 60 will attempt to access resources from the connected devices. However, if a number of stations 60 attempt to access the same resource, such as a server or another computer attached to the network, the resources in the server or computer may not be sufficient to accommodate all the requests from the multiple

workstations 60. Further, a single workstation 60 may be able to acquire all the resources in the server. This means that no resources will be available for the other workstations 60.

An example of a programming interface in accordance with the preferred method is as follows. This example is set forth in detail in Appendix A and incorporated herein by reference. A simplification of the example described in Appendix A follows. The leaky bucket may be created by a programmer or embedded in a system by executing the following routine CreateLeakyBucket. In accordance with the preferred method, the CreateLeakyBucket function may be invoked when a work station 60 is initialized or at some other time while the station 60 is connected to the network.

```
10
    t_return          /*RET    Error code */

    CreateLeakyBucket(
        t_leaky_bucket *pBucket, /*IN    Address of leaky bucket descriptor */
        dword c,               /*IN    Drain amount every t μs */
        dword m,               /*IN    Fill Level maximum */
        dword t)              /*IN    Time in μs between drains */
```

A leaky bucket descriptor having the above form `t_leaky_bucket` may be allocated by the station 60 that invokes the `CreateLeakyBucket` routine. The descriptor may be stored in a memory of the workstation 60.

In the preferred method, each leaky bucket has a "Fill Level". A Fill Level may be defined as a current usage of a resource controlled by the leaky bucket. When a programmer uses the bucket, a numerical value representing the desired amount of resource usage is added to the Fill Level. After a pre-defined period, for example,  $t$  microseconds, a value "c"

is subtracted from the Fill Level. The value c may be defined as an estimate of how much of a resource is available (i.e., not being used by another process) every t microseconds.

Preferably, the Fill Level does not fall below zero.

The bucket size "m" is the maximum allowed Fill Level in the bucket. The difference between the maximum Fill Level and a current Fill Level is called the "credit".

The following functions may also be implemented for configuring the leaky bucket in accordance with the preferred method:

#### ModifyLeakyBucket

ModifyLeakyBucket modifies the parameters m, t, c of a leaky bucket created by calling the routine CreateLeakyBucket. Preferably, the current Fill Level in the leaky bucket is not changed during this routine. The current Fill Level may also not change for a current Fill Level that is greater than the maximum Fill Level m.

t_return	/*RET	Error code */
ModifyLeakyBucket(		
t_leaky_bucket *pBucket,	/*IN	Address of leaky bucket descriptor */
dword c,	/*IN	Drain amount every t $\mu$ s */
dword m,	/*IN	Fill level maximum (max. credit) */
dword t)	/*IN	Time in $\mu$ s between drains (frequency) */

### CreditLeft

CreditLeft returns the remaining credit to the station 60 using a specified leaky bucket. This routine permits a requesting station 60 to determine if the leaky bucket has an adequate Fill Level to execute the requested resource.

5

```
sdword          /*RET    Credit left */  
  
CreditLeft(  
  
    t leaky bucket *pBucket; /*IN    Address of leaky bucket descriptor */
```

## UseLeakyBucket

UseLeakyBucket increments the Fill Level on a specified leaky bucket by a specified amount. This route returns TRUE if the Fill Level can be incremented without the bucket overflowing. This means that a station 60 can access the requested resource. If the available credit is less than AMOUNT, the requested usage of a resource by a station 60, or if another station 60 is waiting to use the requested resource, the Fill Level is not incremented, and the function returns FALSE. This means that a requesting station 60 is generally unable to use the resource until some later time, when enough credit is available to handle the request from the station 60.

```
bool           /*RET Success */  
  
UseLeakyBucket(  
    t_leaky_bucket *pBucket,          /*IN Address of leaky bucket descriptor */  
    dword amount,                  /*IN Usage amount */  
    5     dword maxi,                /*IN Alternative maximum (or 0 for default)  
    */  
    t_leaky_bucket_request *pmsgReq); /*IN Leaky bucket request message */
```

maxi and pmsgReq

If a station 60 using the leaky bucket discovers that the requested usage of resources is not available, the station can attempt to use the resource at some later time. Alternatively, it can use a different resource. The station may also request the leaky bucket mechanism to inform it when the resources are available. In this case, the operating system of the network can be instructed to call the routine pmsgReq. This causes a message to be sent to the requesting station 60 when the requested usage is available.

For example, the argument pmsgReq of t\_leaky\_bucket\_request\*pmsgReq may be NULL to indicate no message should be sent or the network address of a station 60. For a specified network address, the notification message will be sent to the station 60 when the desired credit is available. Before this message is sent, the Fill Level is preferably incremented by at least the amount needed to satisfy the amount of the requested usage.

The parameter maxi may be assigned to a numerical value to specify a maximum Fill Level to be used greater than the value m specified when the leaky bucket was initially created. This can be used when a station 60 requests usage of a resource that would exceed the limits c, t, m of the system. For example, if the resource is important or has a high

priority level, maxi may be set to a high numerical value to override the initial maximum Fill Level m. This allows an important or critical process, such as in a nuclear reactor system, to access a resource for a greater period of time to execute the process. If the process is not important, the value of m is set to logical zero (0). Accordingly, using maxi can vary the credit available for requested resource.

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#### DestoryLeakyBucket

DestoryLeakyBucket prevents a timer t from further decrementing the Fill Level. After this function has been called, there will be no external references to the leaky bucket, and the memory previously occupied by the leaky bucket descriptor t\_leaky\_bucket initiated by calling CreateLeakyBucket may be used for other purposes by the station 60.

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```
void  
DestoryLeakyBucket(  
    t_leaky_bucket *pBucket;      /*IN      Address of leaky bucket descriptor */
```

The following function is an example using the above software tool in accordance with the preferred method. This example uses a leaky bucket with a leaky bucket descriptor &Bucket to allocate the usage of memory in the network system. If the memory can be allocated, as determined by the above UseLeakyBucket routine, the memory is allocated and the function returns OK to indicate that the memory can be allocated. If the leaky bucket does not have enough credit to satisfy the requested usage, the memory is not allocated and the function returns NO\_CREDIT.

```
t_return          /*RET    Error code */  
  
allocate_memory(  
  
    int size,           /*IN     Size of memory to allocate */  
5      void **address)        /*OUT    Address of allocated memory */  
  
{  
    if (!UseLeakyBucket (&bucket, size, 0, NULL))  
        return NO_CREDIT;  
  
    else {  
        *address = malloc(size); /* This is the actual memory allocation */  
        return OK;  
    }  
}
```

The preferred method can be used in real-time environments including industrial process control, weapons systems, network interfaces, and the distribution of power between computation intensive tasks. The preferred method can also be used in a general purpose computing environment.

The preferred method uses a leaky bucket mechanism to enforce voluntary restraint on usage of resources by competing processes. This is a power tool for designers of embedded systems to regulate the usage of resources in an efficient and flexible manner. Further, the preferred method gives programmers the flexibility to request additional usage time for important process request or even to disregard this limitation. Thus, resources can be allocated in a specified manner to favor use for more important processes.

The methods and mechanisms described here are not limited to any particular hardware or software configuration, or to any particular communications modality, but rather they may find applicability in any communications or computer network environment.

The techniques described here may be implemented in hardware or software, or a combination of the two. Preferably, the techniques are implemented in computer programs executing one or more programmable computers that each includes a processor, a storage medium readable by the processor (including volatile and non-volatile memory and/or storage elements), and suitable input and output devices. The programmable computers may be either general-purpose computers or special-purpose, embedded systems. In either case, program code is applied to data entered with or received from an input device to perform the functions described and to generate output information. The output information is applied to one or more output devices.

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A number of embodiments of the present invention have been described.

Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.

What is claimed is:

1           1. A method of managing usage of a resource in a network system, the method  
2 comprising:

3           indicating available credit for usage of a resource; and  
4           regulating usage of the resource by a process based on the indicated available credit.

5 .  
1           2. The method of claim 1, wherein the resource is memory space or system  
2 processor time.

1           3. The method of claim 1, wherein the network is an embedded computer  
system.

1           4. The method of claim 1, wherein the network operates in a real-time  
networking environment.

2           5. The method of claim 1, wherein the method is modeled as a leaky bucket.

2           6. The method of claim 1, further comprising:

3           determining the priority of the resource; and

3           allocating the resource in response to an increased priority of the resource.

1           7. The method of claim 1, wherein the regulating step comprises modifying the  
2 available credit by adjusting a maximum resource usage value.

1           8. The method of claim 1, further comprising notifying the process of the  
2 availability of the credit if the indicated available credit is less than a requested usage amount

1           9. The method of claim 8, wherein the notifying step comprises sending a  
2 message to a network address associated with the process when the requested usage amount  
3 is greater than the available credit.

1           10. A method of managing a plurality of resources in a network having a plurality  
2 of devices, comprising:

3           creating a software tool on each of the plurality of devices accessing the plurality of  
4 resources corresponding to each of the resources; and  
5           using the software tool to regulate the usage of any of the plurality of the resources by  
6 any of the plurality of devices.

1           11. The method of claim 10, wherein the creating step comprises:  
2           allocating a descriptor representative of any of the software tools to any of the  
3 plurality of devices; and  
4           associating with each software tool a maximum usage level.

1           12. The method of claim 11, wherein the using step comprises:  
2           decrementing the maximum usage level of the software tool in response to the use of  
3 the resource associated with the tool by any of the plurality of devices;  
4           calculating an available credit based on the usage of the resource associated with the  
5 tool as a function of the maximum usage level; and  
6           indicating to a device waiting to use the resource associated with the tool of the  
7 available credit.

1           13. The method of claim 12, wherein the indicating step comprises sending a  
2 message to a network address associated with the waiting device to indicate when the  
3 available credit exceeds a specified usage level.

1           14. The method of claim 13, further comprising incrementing the maximum usage  
2           level to at least correspond to the specified usage level.

1           15. The method of claim 11, further comprising overriding the maximum usage  
2           level to allow a device access to one of the plurality of resources.

1           16. The method of claim 10, further comprising destroying the software tool in  
2           response to a request from one of the devices.

1           17. Computer software, residing on a computer-readable medium at a device  
2           connected to a network, comprising instructions to cause the device to perform the following  
operations:

indicating available credit for usage of a resource; and  
regulating usage of the resource by a process based on the indicated available credit.

1           18. A network including a plurality of devices, comprising:  
a plurality of resources running in the network; and  
computer software, residing on a computer readable medium at each device accessing  
the plurality of resources to cause the device to perform the following operations:

5           indicating available credit for usage of a resource; and  
6           regulating usage of the resource by a process based on the indicated available  
7           credit.

1           19. The method of claim 18, wherein the plurality of resources comprise memory  
2           space or system processor time.

1           20. The method of claim 18, wherein the network is an embedded computer  
2           system.

- 1        21. The method of claim 18, wherein the network operates in a real-time  
2        networking environment.

## ABSTRACT OF THE INVENTION

A method is described that can be used to regulate the usage of resources in a network system. A software tool can be used to regulate access to a system resource. The preferred method uses a software tool to enforce voluntary restraint on the uses of resources by competing processes. Further, the software tool can be used to request additional usage time for more important or sensitive processes requesting a specific resource. The preferred method can be used with a general computing environment or in an embedded system.

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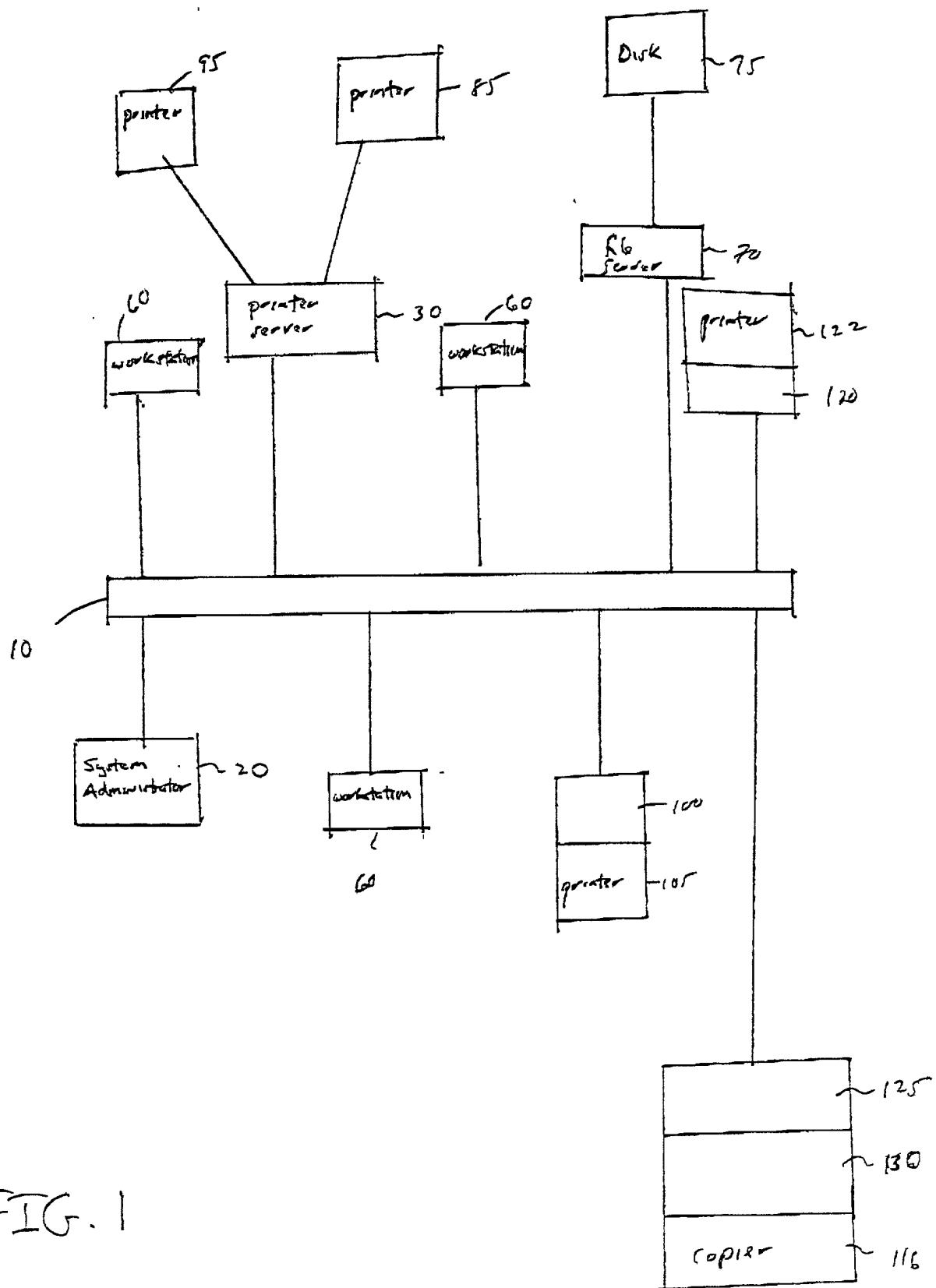


FIG. 1

## COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled REGULATING USAGE OF COMPUTER RESOURCES, the specification of which:

- is attached hereto.  
 was filed on August 26, 1999 as Application Serial No.   and was amended on  .  
 was described and claimed in PCT International Application No.   filed on   and as amended under PCT Article 19 on  .

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information I know to be material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim the benefit under Title 35, United States Code, §119(e)(1) of any United States provisional application(s) listed below:

U.S. Serial No.	Filing Date	Status
60/097,912	August 26, 1998	Pending

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose all information I know to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56(a) which became available between the filing date of the prior application and the national or PCT international filing date of this application:

U.S. Serial No.	Filing Date	Status

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

Country	Application No.	Filing Date	Priority Claimed
			<input type="checkbox"/> Yes <input type="checkbox"/> No
			<input type="checkbox"/> Yes <input type="checkbox"/> No

## Combined Declaration and Power of Attorney

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I hereby appoint the following attorneys and/or agents to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patents issued thereon.

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